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**From:** Bo [bo@praxis-enviro.com]  
**Sent:** 3/22/2017 3:05:08 PM  
**To:** Dan Pope [DPope@css-inc.com]  
**CC:** Davis, Eva [Davis.Eva@epa.gov]; Eleanor Jennings [ejennings@teci.pro]; d'Almeida, Carolyn K. [dAlmeida.Carolyn@epa.gov]; Brasaemle, Karla [KBrasaemle@TechLawInc.com]; Henning, Loren [Henning.Loren@epa.gov]; Arvind Kutty [AKutty@TechLawInc.com]; Cosler, Doug [DCosler@TechLawInc.com]; Wayne Miller (Miller.Wayne@azdeq.gov) [Miller.Wayne@azdeq.gov]; Steve Willis [steve@uxopro.com]  
**Subject:** Re: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

I am a co-author on this paper and referenced it in ADEQs original and follow-on comments to the EBR work plan for inclusion in their modeling. It has the k values I mentioned on last Thursday's call. I apologize for not just forwarding the paper as soon as it was published last year. I conceived of and ran two field mass transfer tests that included the bromide tracer testing and have all the data. Additional interpretation is found in the final report for ESTCP Project ER-200833. The large file can be downloaded at <https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-200833>

I can add comments to the letter re this issue when I get a copy of the draft.

I am working on time of remediation estimates but need Amec mass estimate spreadsheet to finish it.

Sent from my iPhone

On Mar 22, 2017, at 7:08 AM, Dan Pope <DPope@css-inc.com> wrote:

The intro to this paper (*In-situ determination of field-scale NAPL mass transfer coefficients: Performance, simulation and analysis* Journal of Contaminant Hydrology 187 (2016) 31–46) basically sums up some of the problems I have with AF's approach to dealing with COC transfer from LNAPL to GW....

*"Site-specific issues impacting the efficacy of source zone remediation and the long-term persistence of NAPL sources include heterogeneous media of varying hydraulic conductivity combined with the chemical characteristics and spatial distribution [i.e., LNAPL configuration] of NAPL sources. Dynamic contaminant mass transfer impacted by these variables often limits the reliability [i.e., there is high uncertainty] of projections [their predictions estimates comparisons] of remedial efficacy and source longevity [i.e., the source may be around a lot longer than some expect] (Falta et al., 2005a, 2005b; Christ et al., 2010)....*

*The local equilibrium assumption requires thermodynamic equilibrium at the interface between the two phases (Seagren et al., 1999). In effect, mass transfer is assumed to occur instantaneously such that equilibrium is immediately achieved at all locations along the contact plane. Investigators have suggested that this model may be appropriate under conditions where groundwater velocities are relatively low (Powers et al., 1992), where constituent mass fractions remain relatively significant (Powers et al., 1994b) and where contact lengths [i.e., LNAPL configuration] are sufficient to facilitate complete mass transfer (Geller and Hunt, 1993)....*

*While these studies suggest that the local equilibrium model can perform well under certain circumstances, the results generally suggest that the rate limited approach is most appropriate at larger scales due to the potential variability in interfacial area [i.e., LNAPL configuration] and pore velocity [which may be related to effective porosity, for which they only use one value for the whole site, apparently...] (Rivett et al., 1994; Seagren et al., 1999; Grant and Gerhard, 2007; Maji and Sudicky, 2008)....*

*Analysis of intermediate-scale field experiments using comprehensive models suggests that groundwater concentrations adjacent to depleting multicomponent NAPL sources are rate-limited and sensitive [which is why one does sensitivity analyses] to NAPL mass transfer coefficients (Frind et al., 1999; Mobile et al., 2012)...."*

And, of course, in the Abstract: "One impediment to constraining time estimates of source depletion is the uncertainty in the rate of mass transfer between NAPLs and groundwater." And yet AF appears to be content with using the hard-coded equilibrium assumption in their models, rather than doing (at a minimum) some sensitivity analysis to see how changing the transfer rate affects their predictions estimates comparisons for remedy efficacy and timeframes.

I hope we can get some extended input from our modeler on these and other issues with the modeling effort. Not that all the extended input would necessarily be put in the (long...) letter we're preparing, but we need it to back up our expressions of concern we mention in the letter.

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**From:** Davis, Eva [<mailto:Davis.Eva@epa.gov>]  
**Sent:** Wednesday, March 22, 2017 8:39 AM  
**To:** Eleanor Jennings; d'Almeida, Carolyn K.; Brasaemle, Karla; Dan Pope; Henning, Loren; Arvind Kutty; Cosler, Doug; Wayne Miller ([Miller.Wayne@azdeg.gov](mailto:Miller.Wayne@azdeg.gov)); Steve Willis  
**Subject:** RE: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

Thanks for all the input – I will try to get one clean copy for everyone to review one last time. Bo Stewart was inadvertently left off the distribution list – ADEQ may want to forward to him for comments, he is more familiar with TEE modeling efforts and results, some of which are mentioned in this.

Doug, should more be added about the model? I have attached a paper on dissolution measurements made at ST12 which I recently got ahold of – maybe you can interpret it better than I can.

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**From:** Eleanor Jennings [<mailto:ejennings@teci.pro>]  
**Sent:** Wednesday, March 22, 2017 7:59 AM  
**To:** d'Almeida, Carolyn K. <[dAlmeida.Carolyn@epa.gov](mailto:dAlmeida.Carolyn@epa.gov)>; Brasaemle, Karla <[KBrasaemle@TechLawInc.com](mailto:KBrasaemle@TechLawInc.com)>; 'Dan Pope' <[DPope@css-inc.com](mailto:DPope@css-inc.com)>; Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Arvind Kutty <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller ([Miller.Wayne@azdeg.gov](mailto:Miller.Wayne@azdeg.gov)) <[Miller.Wayne@azdeg.gov](mailto:Miller.Wayne@azdeg.gov)>; Steve Willis <[steve@uxopro.com](mailto:steve@uxopro.com)>  
**Subject:** RE: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

Attached are my edits to the version sent from Carolyn's 7:28 PM (EST) below email – really just a few comments. Just trying to help keep track of which draft is flying around and which draft/version is being responded to.

Attached is also an earlier draft (UXO Pro 2) that may have gotten lost in the shuffle, as it contains everything of mine regarding proposed testing (Steve Willis and I worked on a draft and sent both our comments in a combined document). This information was requested again in Carolyn's 7:28 PM (EST) draft from below email, thus why I'm thinking the earlier document may have gotten overlooked (a very easy thing to do with all of the drafts, versions, and edits simultaneously floating around).

MANY thanks for helping to compile this – it's a huge job with this many participants, and the efforts are very appreciated. Let me know if there is anything else I can do to help, or to be of assistance, Eleanor

**Eleanor M. Jennings, M.S. PhD**  
Principal Microbiologist, Biogeochemist

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**From:** d'Almeida, Carolyn K. [<mailto:dAlmeida.Carolyn@epa.gov>]  
**Sent:** Tuesday, March 21, 2017 7:28 PM  
**To:** Brasaemle, Karla <[KBrasaemle@TechLawInc.com](mailto:KBrasaemle@TechLawInc.com)>; 'Dan Pope' <[DPope@css-inc.com](mailto:DPope@css-inc.com)>; Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Arvind Kutty <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller (Miller.Wayne@azdeq.gov) <[Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)>; Steve Willis <[steve@uxopro.com](mailto:steve@uxopro.com)>; Eleanor Jennings <[ejennings@teci.pro](mailto:ejennings@teci.pro)>  
**Subject:** RE: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

I added a few things in light blue

Carolyn d'Almeida  
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*"Because a waste is a terrible thing to mind..."*

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**From:** Brasaemle, Karla [<mailto:KBrasaemle@TechLawInc.com>]  
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**To:** 'Dan Pope' <[DPope@css-inc.com](mailto:DPope@css-inc.com)>; Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; d'Almeida, Carolyn K. <[dAlmeida.Carolyn@epa.gov](mailto:dAlmeida.Carolyn@epa.gov)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Arvind Kutty <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller (Miller.Wayne@azdeq.gov) <[Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)>; Steve Willis <[steve@uxopro.com](mailto:steve@uxopro.com)>; Eleanor Jennings <[ejennings@teci.pro](mailto:ejennings@teci.pro)>  
**Subject:** RE: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

I made a number of edits and included Carolyn's comment. I also edited the text at the end from Dan's original notes.

Karla Brasaemle, P.G.,  
TechLaw, Inc.  
415-762-0566

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**From:** Dan Pope [<mailto:DPope@css-inc.com>]  
**Sent:** Tuesday, March 21, 2017 12:44 PM  
**To:** Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; d'Almeida, Carolyn K. <[dAlmeida.Carolyn@epa.gov](mailto:dAlmeida.Carolyn@epa.gov)>; Brasaemle, Karla <[KBrasaemle@TechLawInc.com](mailto:KBrasaemle@TechLawInc.com)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Kutty, Arvind <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller (Miller.Wayne@azdeq.gov) <[Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)>; Steve Willis <[steve@uxopro.com](mailto:steve@uxopro.com)>; Eleanor Jennings <[ejennings@teci.pro](mailto:ejennings@teci.pro)>  
**Subject:** RE: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

My initial notes on Eva's draft document. Mainly I've added the specific references (it's getting hard to keep track of all the site documents!), and a few comments.

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**From:** Davis, Eva [<mailto:Davis.Eva@epa.gov>]  
**Sent:** Tuesday, March 21, 2017 9:41 AM  
**To:** d'Almeida, Carolyn K.; Dan Pope; Brasaemle, Karla; Henning, Loren; Arvind Kutty; Cosler, Doug; Wayne Miller ([Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)); Steve Willis; Eleanor Jennings  
**Subject:** FW: Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

I've made the first attempt to put forward the reasons why the Agencies believe a phased implementation approach is necessary. I'm leaving the lab and field test descriptions to those who know more about it – please fill it in. I am purposely forwarding Dan's compilation of comments/concerns again, as he made some very good points about expected reactions from the AF/Amec, and we should try to head off those responses now by providing all the information he is suggesting.

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**From:** Dan Pope [<mailto:DPope@css-inc.com>]  
**Sent:** Monday, March 20, 2017 4:02 PM  
**To:** d'Almeida, Carolyn K. <[dAlmeida.Carolyn@epa.gov](mailto:dAlmeida.Carolyn@epa.gov)>; Brasaemle, Karla <[KBrasaemle@TechLawInc.com](mailto:KBrasaemle@TechLawInc.com)>; Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Arvind Kutty <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller ([Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)) <[Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)>  
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**Subject:** Slightly extended DFP Notes on the 3/17/2017 WAFB Conference Call and Path Forward

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**From:** d'Almeida, Carolyn K. [<mailto:dAlmeida.Carolyn@epa.gov>]  
**Sent:** Friday, March 17, 2017 5:55 PM  
**To:** Brasaemle, Karla; Dan Pope; Davis, Eva; Henning, Loren; Arvind Kutty; Cosler, Doug; Wayne Miller ([Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov))  
**Cc:** Eleanor Jennings; Steve Willis  
**Subject:** RE: DFP Notes on the 3/17/2017 WAFB Conference Call

I added some afterthoughts in purple to consider how we use results of (ahem) phased implementation to inform the full scale

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**From:** d'Almeida, Carolyn K. [<mailto:dAlmeida.Carolyn@epa.gov>]  
**Sent:** Friday, March 17, 2017 3:10 PM  
**To:** Dan Pope <[DPope@css-inc.com](mailto:DPope@css-inc.com)>; Davis, Eva <[Davis.Eva@epa.gov](mailto:Davis.Eva@epa.gov)>; Brasaemle, Karla <[KBrasaemle@TechLawInc.com](mailto:KBrasaemle@TechLawInc.com)>; Henning, Loren <[Henning.Loren@epa.gov](mailto:Henning.Loren@epa.gov)>; Kutty, Arvind <[AKutty@TechLawInc.com](mailto:AKutty@TechLawInc.com)>; Cosler, Doug <[DCosler@TechLawInc.com](mailto:DCosler@TechLawInc.com)>; Wayne Miller ([Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)) <[Miller.Wayne@azdeq.gov](mailto:Miller.Wayne@azdeq.gov)>  
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**Subject:** RE: DFP Notes on the 3/17/2017 WAFB Conference Call

My notes from today:

- Adopt Phased Approach to implementation to collect site specific data to refine model, remedial timeframe estimate and performance criteria.

- Collect samples for microbial analysis to determine bacteria present, evaluate need for bioaugmentation.
- Perform lab testing to evaluate impact of temperature and sulfate loading rates on microbial population
- Incorporate phased implementation in specified areas differentiating between heavy LNAPL areas and dissolved phase areas in LSZ, UWBZ and CZ 3-6 months should be sufficient to evaluate degradation rate in dissolved phase areas, up to a year to evaluate degradation rate in heavy LNAPL areas Will need observation wells spaced within 6 months travel time of injection wells; bromide tracer useful for evaluating flow distribution around well.

Evaluate whether sulfate and tracer reach observation wells, then whether amendment is achieving biodegradation or not

- Update model to verify remedial timeframe, performance evaluation criteria and optimize full scale implementation
- Grid the full treatment area into optimization zones based upon existing conditions identified during characterization: Heavy LNAPL vs dissolved phase, temperature, microbial population, available sulfate, etc for optimized treatment, including possible bioaugmentation
- Install or designate observation wells within gridded optimization zones to evaluate remedy progress
- ADEQ working on alternative model

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*"Because a waste is a terrible thing to mind..."*

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**Sent:** Friday, March 17, 2017 2:35 PM  
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**Subject:** DFP Notes on the 3/17/2017 WAFB Conference Call

## DFP Notes on the Friday March 17, 2017 WAFB Conference Call:

Loren has said that **performance criteria** are to be emphasized.

## Why are regulators proposing a phased implementation?

- Site conditions have changed from those contemplated in the ROD for EBR/MNA
- EBR/MNA has not been tested and proven effective at a site of this size, complexity, and source mass – particularly in terms of the timeframe contemplated
- Therefore, a phased implementation (initially limited in terms of the volume of the subsurface applied) is indicated for proof of concept, and to provide data for EBR design and performance criteria.

## Modeling

AF should provide a predictive modeling approach suited to determining timeframes for EBR and MNA to reach the respective goals for those remedy approaches. This modeling will include items related to performance criteria (timelines, triggers, COC concentrations, etc.)

## Pre-injection Analyses

Have AF propose their ideas for pre-injection analysis to assess microbiology and geochemistry initial conditions, for comparison to post-injection analyses.

We can propose our own pre-injection analyses to assess microbiology and geochemistry initial conditions, and try to come to a meeting of the minds with AF.

These pre-injection and post-injection tests (for the phased implementation) would form another set of performance criteria; that is, to determine if the appropriate bug populations are developed to proper levels and activity.

## Phased Implementation

A phased implementation, applied to a limited area of the site (but all vertical zones) would be the first major milestone (performance criterion) for success; i.e., if the COCs concentrations are lowered to the required concentrations, and stay there, that would be a major step to indicate feasibility of EBR.

A phased implementation could consist of starting EBR at selected sections of the site (i.e., essentially just a portion of what they have already planned for full-scale EBR, so there would not have to be any major changes in terms of approach). That is, pick wells with substantial LNAPL, at least one well in each of the various vertical zones, have injection wells upgradient of the LNAPL wells, and monitoring wells immediately downgradient of the wells, and inject sulfate, etc., as planned for the full-scale EBR. If AF can timely remediate that well so that the COC GW concentrations in those representative wells and the downgradient monitoring wells are (and remain over time) below EBR goals, then that would be strong evidence that a full-scale approach could work.

The chosen LNAPL well should have significant LNAPL – more than a sheen – at least two inches of LNAPL fairly consistently, so that actual remediation of GW in contact with substantial LNAPL can be assessed.

Chosen well should be at elevated temperature, to correspond with the general site conditions.

Reagent injections (sulfate, etc.) should reflect those concentrations, rates, volumes, etc. that are proposed for full-scale EBR.

Assuming the phased implementation continues for at least a year, the changes around the injection wells in terms of microbiology, sulfate concentrations, sulfide production, hydrogen sulfide generation, precipitation of iron sulfides, possible aquifer plugging, changes in pH, etc., can be monitored and evaluated for viability of a full-scale remedy, and any likely dangers, showstoppers, etc.

Fouling should be assessed for all wells (injection, LNAPL, monitoring), to determine the likely needs for well reworking, refurbishing, eventual replacement, etc. This is particularly important for the follow-on contractor (after AMEC's contract expires) to have an idea of long-term costs, and how to bid.

The downgradient monitoring transect can not only monitor COC changes, but also assess the geochemical footprint of downgradient locations, which would be pertinent to evaluating possible enlargement of a sulfate/etc. plume at full scale.

Also, the distribution and concentrations of sulfate achieved downgradient of the injection transect is of great interest. The AF model indicates they can get a reasonable (to them) sulfate distribution, but reality in subsurface environments is often different from the models. The field study should be designed to provide suitable data to design injection well spacing, injection rates, injection concentrations, pressures, etc., so as to achieve useful sulfate concentrations across the site.